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CONSTRUCTION PROGRESS IN THE CLEVELAND DIVISION OF WATER[1]

By A. V. RUGGLES[2]

STATISTICS OF EXISTING SYSTEM

The water supply system of Cleveland is separated into four service districts, between the following elevations:

SERVICE DISTRICT	ELEVATIONS		CORRESPONDING EQUALIZING RESERVOIR				
	From	To	Name	Elevation of overflow	Static head on upper limit of service district	Capacity full, million gallons	Put in services
Low	Lake	120	Fairmount (existing)	170.0	50.0	80.0	1885
Low	Lake	120	Baldwin (under construction)	228.5	108.5	130.0	
1st high	120	250	Kinsman	325.0	75.0	35.0	1885
2nd high	250	500	Warrensville Res.	575.0	75.0	22.0	1914
3rd high	500	665	Warrensville Tower	810.0	145.0	0.2	1915*

* In present location.

The other way, reference to the map shows the water supply system separated into an East Side and a West Side by the wide and deep valley of the Cuyahoga River, with connections across the valley at six points, as shown in tables on following page.

The second intake, like the first, was on the West Side, to supply the only pumping station the city then had. In the good old days of our hale and hearty forefathers, typhoid was no stranger, and the completion of this second intake, over a mile from shore, was expected to insure a pure supply for a much longer period than proved to be the case.

Since that time two more intakes have been completed, to replace the now sealed Crib no. 4, and before 1940 two more must be built,

Connections across Cuyahoga River Valley

NAME	SERVICE DISTRICT	INSIDE DIAMETER OF TUNNEL	SIZE AND KIND OF PIPE	DISTANCE IN A STRAIGHT LINE FROM LAKE FRONT	Finished
		feet			
Main Street	Low	8	48 inch steel	Less than 1 mile	1897
St. Clair	Low	7½	40 inch W. I.	Less than 1 mile	1891
Superior	Low	8	48 inch steel	Less than 1 mile	1897
Central Ave.	Low	10	None	1¼ mile	1916*
Clark Ave.	Low	8	48 inch steel	3 miles	1895
Denison	1st high	None	30 inch steel submerged pipe	4 miles	1897

* Will not be used until question of straightening the river is settled.

Past, present and future intakes from Lake Erie

DATE PUT IN SERVICE	NAME OF INTAKE	DISTANCE FROM SHORE IN A STRAIGHT LINE	TUNNEL		LOCATION	PUMPING STATION SUPPLIED
			Inside diameter	Lining		
1856		300 feet	50 inch W.I. submerged pipe		W. 58th St.	Division
1874	Crib 4 now sealed submerged	1¼ miles	7-feet and a 5 feet	Brick Brick	W. 45th St.	Division
1904	Crib 3 steel superstructure	4 miles	9 feet	Brick	E. 49th St.	Kirtland
1917	Crib 5 submerged	4 miles	10 feet	Concrete blocks	W. 45th St.	Division
1930	New East				Farther east than Kirtland	New East
1940	New West				Farther west than Division	New West

giving a total of four in use in 1940, and it will be noticed that the last two that were built and the next two to be built, come alternately East Side and West Side, to meet the growing demands for water.

Pumping facilities, present and adopted for immediate installation, are as follows:

Division Station, W. 45th Street and Lake Front. Low lift pumps to Division Filtration Plant, total pump capacity 260 m. g. d.

Low service pumps, total pump capacity 90 m. g. d.

First high service pumps, total pump capacity 50 m. g. d.

Kirtland Station, E. 49th Street and Lake Front. Existing low service pumps, 130 m. g. d. To be installed, L. S. pumps, 70 m. g. d.

Existing Fairmount Station, Woodhill Road, between Fairmount Road and Quincy Avenue, 3 miles southeast from Kirtland Sta. Pumping from Fairmount Reservoir:

First high service pumps, 10 to 22 m. g. d.

Second high service pumps, 9 to 14 m. g. d.

New Fairmount Station, to replace existing station, at same location. Low lift pumps, to lift unfiltered water from Fairmount Reservoir to Baldwin Filtration Plant, surrounding Baldwin Reservoir (now under construction), 200 m. g. d. Pumping from Baldwin Reservoir:

First high service pumps 40 m. g. d.

Second high service pumps 60 m. g. d.

Kinsman Station (now under construction), Kinsman Road near E. 116th St., 1½ miles south of Fairmount Sta. Pumping from Kinsman Reservoir, second high service 5 m. g. d.

Warrensville Station, Green Road, near Warrensville City Farm, 5½ miles east by southeast from Fairmount Sta. Pumping from Warrensville Reservoir, third high service 1.4 m. g. d.

PLANNING FOR THE FUTURE

Leading up to the choice of Baldwin as location for our second filtration plant, the determination of its capacity and that of the pipe lines leading to and from it, and the decision as to ultimate first High and second High pump capacity to provide at the reconstructed Fairmount Pumping Station, we have carried through a careful series of studies to determine the future demands for water up to 1960, and it is the purpose of this paper to explain briefly the methods pursued and to put on record, for the benefit of those interested, the vital statistics obtained. It has been found to be a reasonable expectation that we will be furnishing water by 1940 to the whole of Cuyahoga County; in fact we have for some years sent water into part of Lake County, to the east, over 17 miles from the City Hall. The following table shows that this growth in the next 20 years is not only a three fold expansion but in major degree in the high service districts.

In determining upon the program of expansion to meet future demands for water we reached the conclusion that the existing East Side and West Side tunnels have ultimate capacities of 165 and 156 m.g.d. respectively. As the demand will in ten years reach an amount in excess of the combined deliveries of these two tunnels

Elevation of Various Points

In Reference to
Cleveland City Datum · Mean Sea Level

City Datum	0		572.52
U.S.Government Zero of Lake Level of Cleveland	−2.34		572.86
Water in Fairmount Reservoir at bottom of overflow pipe	170.3		742.5
Bottom of Fairmount Reservoir at drain opening	150.3		722.5
Capacity of Fairmount Reservoir	61,265,600		
Year when put in service	Nov. 29, 1885		
Water in Kinsman Reservoir at bottom of overflow pipe	324.2		899.4
Bottom of Kinsman Reservoir at drain opening	302.4		877.6
Capacity of Kinsman Reservoir	33,615,600		
Year when put in Service	1885		
Water in Warrensville Reservoir at bottom of overflow pipe	575.5		1150.7
Bottom of Warrensville Reservoir at drain opening	554.6		1129.8
Capacity of Warrensville Reservoir	22,250,000		
Year when put in service	Sept 24, 1914		
Water in Warrensville Water Tower at bottom of overflow pipe	810.0		1382.2
Bottom of Warrensville Water Tower	758.9		1331.1
Ground at Warrensville Water Tower	677.0		1282.2
Capacity of Warrensville Water Tower	200,000		
Year when put in service	Jan 28, 1915		
Dividing line of L.S. and 1ˢᵗ H.S.	1200		692.2
Dividing line of 1ˢᵗ H.S. and 2ⁿᵈ H.S.	2500		825.2
Dividing line of 2ⁿᵈ H.S. and 3ʳᵈ H.S.	3000		1075.2

Border line of Townships and Villages ⊢·+·+·+·+·+·⊣
Contour lines ⌐‿─‿‿─

Scale 1"=1 mi.

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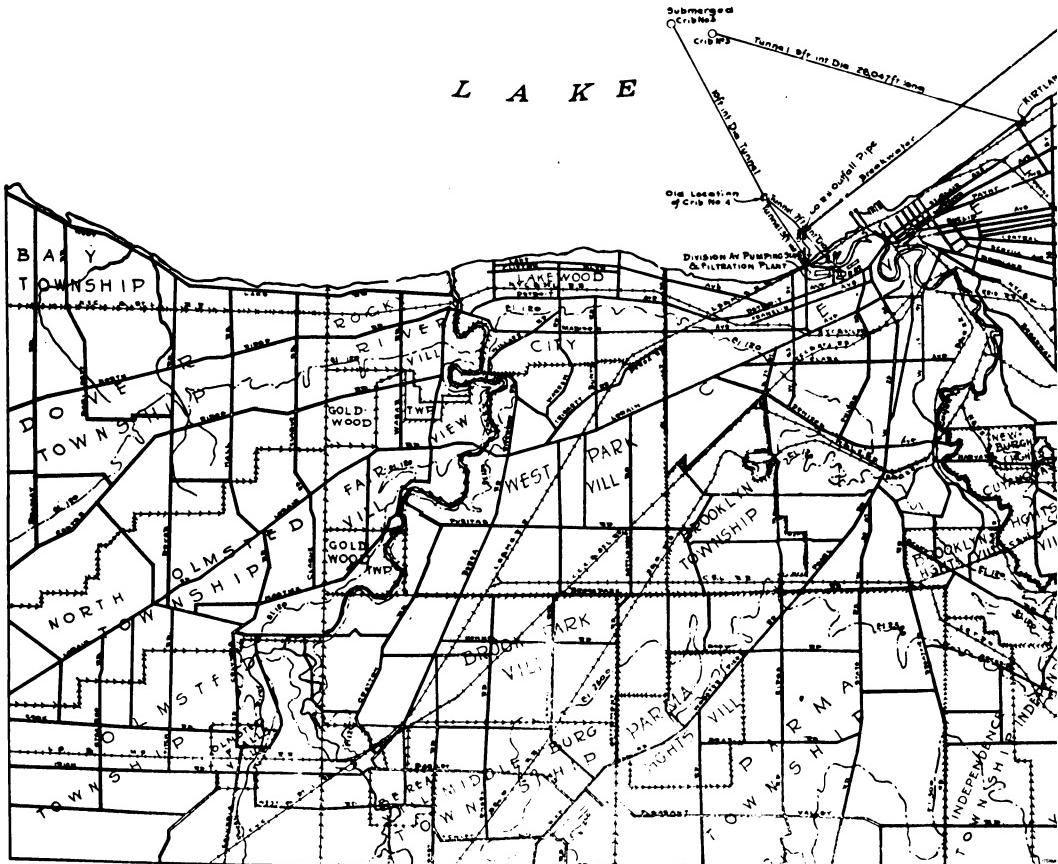
Fig. 1. Map of Cleveland and Suburbs Showing Pumpin
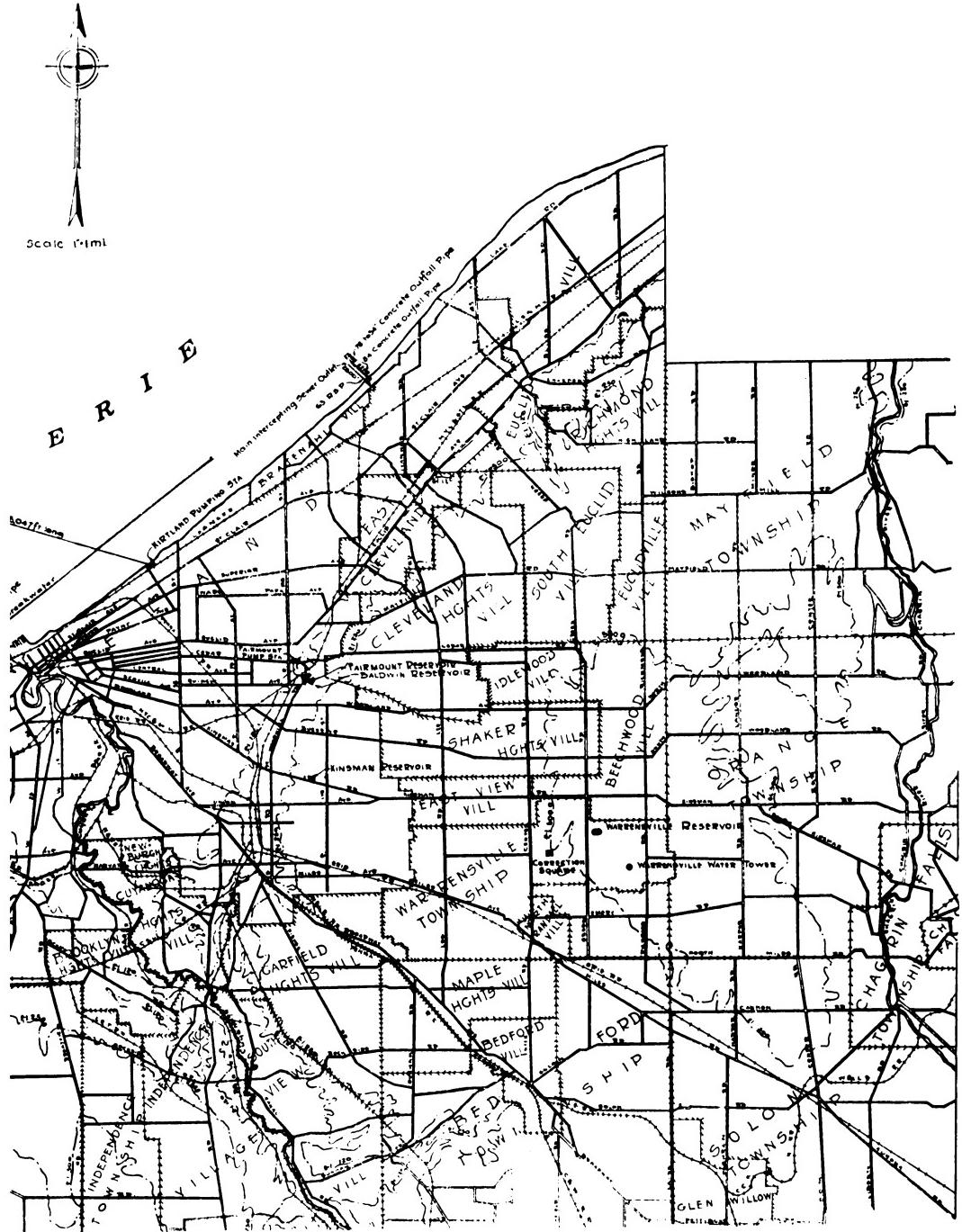
s Showing Pumping Stations, Reservoirs. Towers, etc.

Area in square miles, supplied with water by City of Cleveland

SERVICE DISTRICT	1920			1940
	City	Suburbs	Total	Total
Low...............................	35	12	47	73
First high...........................	14	25	39	129
Second high.........................	7	30	37	198
Third high..........................	0	3	3	56
Totals...........................	56	70	126	456*
				19†
Total area to be supplied in 1940..............................				475

* Total area of Cuyahoga County.
† Part of Lake County.

it was necessary to find the most economical location and size of the next two tunnels needed in 1940, to bring the water to shore, and also the most economical size, location and times of successive partial installations of the structures needed to purify, pump, store and deliver this water to the consumers.

Investigations were carried on along four lines: First, flow in large mains; second, pressure; third, population; fourth, consumption of water.

FLOW IN LARGE MAINS

In 1919 we built over 30 pitometer vaults at strategic points on large mains and measurements of velocities at these points and also at some other pitometer vaults built previously, gave valuable information on the extent to which these mains are being pushed at present, and aided in determining at what future dates additional mains will be required to help them out. Most of the runs were 24 hours, a few were 48 hours, taking in a Sunday and Monday, and in a few cases simultaneously with the pitometer measurements we observed pressures on hydrants in the neighborhood of the pitometer vault, pressures and rate of pumpage at the stations and fluctuations in level in the reservoir corresponding.

PRESSURES

We have recording pressure gauges at the pumping stations and at some 35 fire stations. The charts are changed daily and once a week mailed by the firemen to the office of the Commissioner of
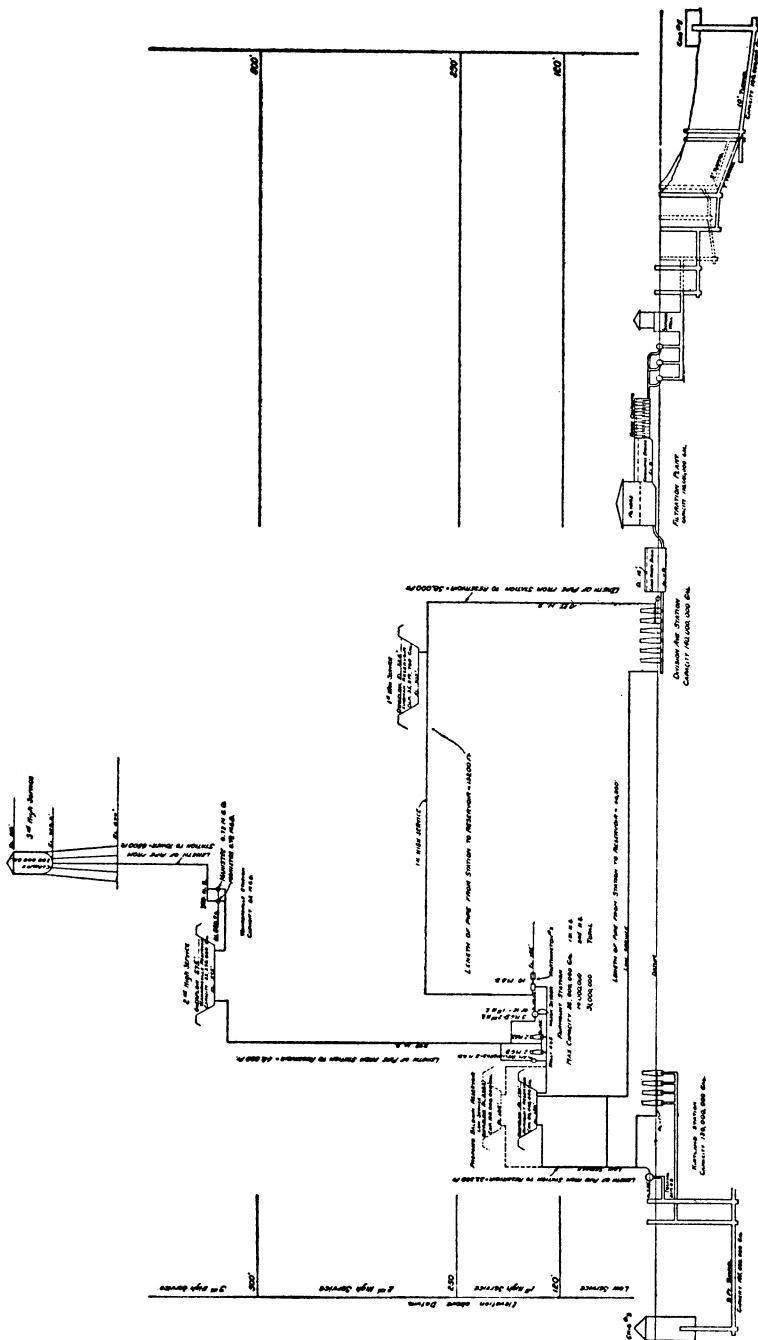
FIG. 2. PROFILE OF MAIN FEATURES OF WATER SUPPLY OF CLEVELAND

Water. The gauges are inspected at intervals by one of the engineers of the Division of Water, who keeps them supplied with charts, ink, etc. We keep in the office, for each pressure gauge, a graphical record, for each month, of the average pressure at 9:00 in the morning, when the industrial and household demands join to bring pressures down rather low. On the same diagram we show the lowest pressure during the month at 9:00 a.m., the average 9:00 a.m. pressure for the year and static pressure due to the reservoir. These records prove very useful also to refer to in connection with complaints of poor pressure.

POPULATIONS

In forecasting future populations in what now constitutes the City of Cleveland and all other cities and villages in Cuyahoga County, we correlated all discoverable estimates from existing sources, giving most credence to the United States Census and comparing with that the figures of the Division of Water, the Rapid Transit Commission, the Cleveland Board of Education, the Cleveland Board of Elections, Cleveland Police Department, the Cleveland Telephone Company and some others.

It became necessary to carry through these estimates, forecasting population and consumption of water, in 1919, just before the Federal Census was taken. When the Federal Census figures became available to us, we found that we had been over-sanguine in our forecasts. There were many people here in Cleveland, as elewhere in the country, in large cities and small towns, who were firmly convinced that the Federal Census figures were considerably below the truth, due to both floaters and permanent residents not being listed by the enumerators. To see if we could discover any great error in the Federal Census we made a test count in Ward 21, an East Side ward, partly middle class residential and partly business, working in conjunction with the Bureau of Municipal Research, the count being taken by Division of Water meter readers. This was done, we think at least as carefully as the Federal enumeration, and the excess which it showed over the Federal return was almost precisely that which would be added by natural growth during the number of months which elapsed between the taking of the two counts. This test count reassured us in the belief that the Federal Census is the best possible guide to population figures.

An article in the *Engineering News-Record* of November 4, 1920, "Planning the Future of the Cleveland Water Supply," gives our figures as they stood prior to receipt by us of the detailed results of the United States 1920 census. All the figures that follow here are as we revised them after receiving the complete United States 1920 census results, which had the effect of bringing down our population estimates and raising our per capita consumption figures.

Readings from population curves

YEAR	(1) CUYAHOGA COUNTY		(2) POPULATION SUPPLIED		(3) CITY OF CLEVELAND		(4) POPULATION IN AREA OF 26 WARDS	
	Population	In- crease*	Population	In- crease*	Population	In- crease*	Population	In- crease*
1860			6,730					
1870	132,010		27,300	4.060	92,829			
1880	196,943	1.491	70,000	2.564	160,146	1.729		
1890	309,970	1.571	216,000	3.085	261,353	1.632	264,290	
1900	439,120	1.417	388,000	1.795	381,768	1.460	381,900	1.443
1910	637,425	1.45	609,000	1.570	560,663	1.466	567,000	1.485
1920	943,469	1.48	907,141	1.487	796,836	1.42	796,836	1.405
1930	1,261,150	1.34	1,213,650	1.338	1,130,000	1.419	979,200	1.228
1940	1,640,350	1.30	1,624,850	1.338	1,600,000	1.416	1,104,850	1.128
1950	2,090,000	1.273	2,090,000	1.286	2,090,000	1.305	1,216,900	1.100
1960	2,500,000	1.195	2,500,000	1.195	2,500,000	1.195	1,313,800	1.080

YEAR	DIFFERENCE BETWEEN (1) AND (3)		DIFFERENCE BETWEEN (1) AND (4)		DIFFERENCE BETWEEN (2) AND (4)	
	Population	Increase*	Population	Increase*	Population	Increase*
1870	39,181					
1880	36,797	0.94				
1890	48,717	1.326	45,730			
1900	57,352	1.178	57,220	1.252	6,100	
1910	76,762	1.337	70,425	1.230	42,000	6.885
1920	146,633	1.910	146,633	2.085	110,305	2.633
1930	130,150	0.888	281,950	1.922	234,450	2.125
1940	40,350	0.310	535,500	1.897	520,000	2.22
1950	0	0	873,100	1.631	873,100	1.678
1960	0	0	1,186,200	1.358	1,186,200	1.358

* The figures in this column represent the ratio of the population in any year to that ten years earlier.

For each of the 26 wards in Cleveland, for the ward area as it existed in 1917, a population curve was adopted, based mainly

on United States Census figures, but guided by superimposed curves of population estimates by Board of Education, Board of Elections and Cleveland Telephone Company. These curves were all carried to 1960 and for any year total up to the proper figure on the Total Curve. Similarly separate population curves, up to 1960, were drawn for each suburban city, village and township out to the limits of Cuyahoga County, these likewise being made, for any year, to conform in total to the proper Total Curve. All of the figures, put in tabular form, were divided up between the four service districts, so that we could pick off for any year up to 1960, the population (and corresponding demand for water) for any service district, in, for instance, the entire region east or west of the Cuyahoga River; or for any group of City wards or suburban communities; so as to give the population to be supplied from one pumping station, reservoir or main, or any other combination desired.

Following are figures on "Density" or "Population per Acre."

	CLEVELAND			EAST CLEVELAND	LAKEWOOD
	Ward of maximum density	Ward of minimum density	Average		
1920	62.0	10.3	22.2	14.3	12.1
1930	74.6	14.0	27.3	22.8	20.5
1940	85.0	14.2	30.8	31.4	29.0
1950	95.5	13.1*	33.7	38.0	35.9
1960	106.0	11.8*	36.4	41.8	40.6

* These figures showing decrease in density are for Ward 9, as it now exists, of 1055 acres, on the lake front just east of the Cuyahoga River, where business buildings will gradually drive out resident population.

CONSUMPTION OF WATER

To determine the actual rate of consumption of water in the various parts of the city, and the past and probable future variations in these rates, a water consumption ledger was begun in 1917, under the direction of the writer. In this were entered figures of actual consumption of water from the meter reading books for six-month periods, showing winter consumption separate from summer; large connections 1 in. and over, separate from those smaller, thus practically separating industrial from domestic use; and keeping consumption separate as between the different service districts. A continuous record of $5\frac{1}{2}$ years, from 1914 to 1919, has been thus summarized by wards.

Following is shown for each of the six-month periods the "Pump-age Factor" or the factor between station pumpage and consumption as indicated by meter reading, this factor representing slippage of pumps and meters, unmetered water, leakage and other losses, as shown on following page.

The figures previously mentioned, summarizing water consumption by wards, 1914 to 1919, were combined with (1) the population figures and (2) the "Pumpage Factor," so as to give us summaries by wards of "Gallons per Capita Daily of Station Output."

The tables of statistics resulting therefrom are too voluminous to present here, but will be gladly furnished by the Cleveland Water Department to any interested in going into them in detail.

They have the unique advantage of separating water consumption of *large* connections, the industrial use, from that of *small* connections, the domestic use.

Below is a brief summary giving some of the salient features of the statistics mentioned above.

Cleveland became completely metered in 1909, with a per capita daily consumption that year of 94 gallons, as compared with 172 in 1901, when only a small part was metered.

Gallons per capita daily consumption in various districts for the years 1914 to 1919 inclusive

	ENTIRE POPULATION SUPPLIED	ENTIRE LOW SERVICE IN CITY (OMITTING WARD 9)			WARD 9 BUSINESS AND MFG. DISTRICT			ENTIRE 1ST H. S. IN CITY			ENTIRE 2ND H. S. IN CITY		
	Total	Small	Large	Total	Small	Large	Total	Small	Large	Total	Small	Large	Total
Average	123.9	51.4	61.7	113.1	103.6	432.8	536.4	48.9	49.7	98.6	30.3	11.1	41.4
Min......	107.3	45.5	49.9	95.4	88.9	374.5	463.4	43.4	38.4	81.8	20.8	9.6	30.4
Max......	146.6	58.6	76.9	135.5	121.8	523.0	644.8	53.4	65.1	118.5	41.7	12.0	53.7

Gallons per capita daily consumption in individual wards for any year 1914 to 1919 inclusive

		Small	Large	Total				Small	Large	Total	Small	Large	Total
Min......		24.1	6.6	48.6				35.4	0.5	45.4	17.5	2.7	20.2
Max......		82.1	240.0	288.4				92.7	89.0	181.7	42.8	62.6	99.3

LOW SERVICE		FACTORS	DIFFERENCE FROM AVERAGE	
				per cent
1914	Winter......................	1.188	0.015	1.28
1914	Summer......................	1.203	0.030	2.56
1915	Winter......................	1.125	0.048	4.09
1915	Summer......................	1.125	0.048	4.09
1916	Winter......................	1.109	0.064	5.45
1916	Summer......................	1.103	0.070	5.96
1917	Winter......................	1.150	0.023	1.96
1917	Summer......................	1.149	0.024	2.04
1918	Winter......................	1.256	0.083	7.07
1918	Summer......................	1.229	0.056	4.77
1919	Winter......................	1.261	0.088	7.50
	Sum......................	12.898	0.549	46.77
	Average......................	1.173	0.050	4.25

FIRST HIGH SERVICE		FACTORS	DIFFERENCE FROM AVERAGE	
				per cent
1914	Winter......................	1.475	0.154	11.65
1914	Summer......................	1.362	0.041	3.10
1915	Winter......................	1.310	0.011	0.83
1915	Summer......................	1.274	0.047	3.55
1916	Winter......................	1.330	0.009	0.68
1916	Summer......................	1.225	0.096	7.25
1917	Winter......................	1.224	0.097	7.24
1917	Summer......................	1.311	0.010	0.76
1918	Winter......................	1.209	0.012	8.49
1918	Summer......................	1.332	0.011	0.83
1919	Winter......................	1.475	0.154	11.65
	Sum......................	14.527	0.742	56.13
	Average......................	1.321	0.067	5.10

SECOND HIGH SERVICE		FACTORS	DIFFERENCE FROM AVERAGE	
				per cent
1914	Winter......................	1.400	0.071	4.82
1914	Summer......................	1.329	0.142	9.66
1915	Winter......................	1.632	0.161	10.95
1915	Summer......................	1.477	0.006	0.41
1916	Winter......................	1.454	0.017	1.16
1916	Summer......................	1.332	0.139	9.45
1917	Winter......................	1.614	0.143	9.70
1917	Summer......................	1.477	0.006	0.41
1918	Winter......................	1.533	0.062	4.21
1918	Summer......................	1.461	0.010	0.75
1919	Winter......................	1.477	0.006	0.41
	Sum......................	16.186	0.743	51.86
	Average......................	1.471	.067	4.71

Values adopted for the future are as follows:

	1925		1930		1935		1940	
	G. p. c. d.	Per cent	G. p. c. d.	Per cent	G. p. c. d.	Per cent	G. p. c. d.	Per cent
Total population supplied with water. All service distficts...	160	100.0	165.0	100.0	170.0	100.0	175.0	100.0
Total low service including ward 9......................	165	103.1	169.8	102.9	175.2	103.1	180.0	103.0
Total low service excluding ward 9......................	144	90.0	146.0	88.5	148.8	87.5	151.4	86.5
Total first high service.........	168	105.0	173.3	105.0	174.2	102.5	175.0	100.0
East side second high service...	128	80.0	135.3	82.1	139.4	82.0	143.5	82.0
West side second high service...	96	60.0	115.5	70.0	127.5	75.0	140.0	80.0
East and West Sides, third high service.....................					127.5	75.0	140.0	80.0

G.p.c.d is "Average gallons per capita daily of station output."
Per cent is "Percentage which this is of the g.p.c.d. for entire population supplied with water."

It is to be seen that the figures above show marked variation in the past years but they serve to give a basis for allowances for the future, and are of especial assistance in planning to meet the needs in the high service districts where the growth will be most rapid and where the needs must be met mainly from booster stations distant from the lake shore. For the new Fairmount Pumping Station, for example, which we are to build immediately, they have enabled us to delimit the 1st and 2nd High Service outputs which it will be economical for us to serve from this point, and thus fix the ultimate 1st and 2nd High Service pump installations to house in this station and the size and location of the necessary mains to provide to carry the water.

The figures so far discussed are *average* daily demands. The relation between *average* and *maximum* daily pumpage, for the city as a whole, in the past, has been as shown in table on following page.

YEAR	DAILY PUMPAGE, M. G. D.		RATIO
	Maximum	Average	
1900	88.5	67.1	1.32
01	89.0	69.6	1.28
02	93.0	69.95	1.33
03	92.0	62.0	1.48
04	107.0	61.6	1.74 maximum
05	93.0	60.4	1.54
06	86.0	59.0	1.46
07	79.0	58.9	1.36
08	79.0	52.0	1.52
09	79.5	52.8	1.51
10	92.0	61.0	1.51
11	100.0	65.7	1.52
12	91.0	73.1	1.25
13	107.0	76.8	1.39
14	111.0	82.0	1.35
15	111.5	80.0	1.395
16	127.0	95.65	1.33
17	146.0	103.9	1.405
18	177.5	123.6	1.44
19	167.6	127.3	1.31
20	167.1	141.0	1.185 minimum
			1.411 average

Study of this relation for the separate service districts led us to adopt the following values:

Ratio of maximum to average daily consumption

	1920	1925	1930	1935	1940
All services combined............	1.40	1.375	1.35	1.325	1.30
Low service....................	1.45	1.425	1.40	1.375	1.35
First high service...............	1.55	1.525	1.50	1.475	1.45
Second high service.............	1.75	1.6875	1.625	1.5625	1.50

The testimony of our records is that as the demand for water increases in a service district, this ratio becomes smaller and less variable. In carrying through the detailed figures to determine pump installations and mains for the various new booster stations, we have provided pump and main capacities to meet maximum *daily* flows, without too high velocities, supplementing these, in each

service district, with enough reservoir capacity to meet maximum *hourly* fluctuations in demand. For the Baldwin-Fairmount Project, for example, with raw water being pumped at a constant rate from Kirtland Station to Fairmount Reservoir and then boosted at a constant rate from Fairmount Reservoir to Baldwin Filtration Plant; filtered water then entering Baldwin Reservoir at a constant rate of 150 m.g.d.; Baldwin Reservoir would then take care of such maximum *hourly* fluctuations as a study of our past records leads us to expect, with a variation in level of less than 7 feet.

In prophesying a continued growth in per capita consumption in the Low Service district, beside the steady growth in the recent past, there are other features of importance. Baldwin Reservoir will give 55 feet or 24 lbs. more pressure than Fairmount Reservoir now gives, tending to increase both legitimate use and leakage somewhat. Factories now use 60 per cent of our total supply and the greater part of these are in the Low Service. The exceptional advantages offered by Cleveland as a location for factories with iron ore coming by water from the upper lakes, coal by rail from the south, food supplies near at hand, and radiating railroads by which to ship away the manufactured products, all assure a continued industrial growth and industrial demand for water.

Total future maximum daily demands for water are estimated as follows, in million gallons daily:

	1930	1940	1950	1960
East of River				
Low	111.4	126.7	138.8	148.8
Ward 9	30.0	38.0	47.7	57.1
First high	34.95	43.8	48.7	50.9
Second high	29.3	51.0	72.6	87.8
Third high	1.1	3.0	5.7	7.6
Sum of above East Side Figures	206.75	262.5	313.5	352.2
West of River				
Low	47.1	57.1	66.4	75.4
First high	38.4	66.8	93.7	112.8
Second high	0.65	4.2	10.1	16.7
Third high		0.8	2.8	4.5
Sum of above West Side Figures	86.15	128.9	173.0	209.4
Total of above figures	292.90	391.4	486.5	561.6

	1930	1940	1950	1960
Estimated Total Pumpage from Lake, deducting repumpage and discounting the fact that maxima do not occur in all parts of system simultaneously	273.0	363.0	466.0	547.5
Total low service........................	188.5	221.8	252.9	281.3
Total first high service..................	73.35	110.6	142.4	163.7
Total second high service................	29.95	55.2	82.7	104.5
Total third high service..................	1.1	3.8	8.5	12.1

THE RESULTANT PROGRAM

Computations were carried through in detail to determine the location and capacity of the various additional intakes, tunnels, shore pumping stations, filtration plants, inland booster stations, reservoirs and mains to meet these demands, and the date that each part must be in readiness for service, likewise the ultimate capacity it has been found economical to provide at each point, so that enough land may be bought at the outset and partial filtering and pumping installations so made as to permit of expansion later to final capacities. In comparing the results of the 1920 Sanitary Survey of Lake Erie by Mr. J. W. Ellms, Engineer of Water Purification, made to show the best locations of the new east and new west intakes as affected by quality of the lake water, with the results of these computations, made to show where the water should be brought to shore, in order to be delivered economically to the desired points of consumption, we found that our estimates of demands from 1940 to 1960, made only after receiving the 1920 Federal Census figures, threw new light on the subject, and had the result of bringing the locations of the two future shore pumping stations nearer the present ones. In other words, for a problem as large and complicated as this, 20 years ahead is not far enough to look. Besides providing enough capacity at all four shore pumping stations which are to be in use in 1940, to meet all maximum demands, it has been found that with comparatively small additional expense for mains connecting the stations and by installing successive pump increments faster than we would otherwise, we can meet the needs, on a day when demands are 10 per cent higher than average for that year, in 1930 with Kirtland Station shut down, leaving the entire burden on Division and New East Stations; and likewise meet a

demand 10 per cent over average, in 1940, with any one of the four shore pumping stations out of service.

The figures have demonstrated the necessity of having ready for use prior to 1930 a third intake crib and tunnel of a capacity of 165 m.g.d. located a few miles east of Kirtland Station, with pumps and filters installed at first up to a capacity of 75 m.g.d. and land acquired at the outset and so laid out as to provide for ultimate extension to the full capacity of the tunnel.

Just prior to 1940 a fourth intake and tunnel of 165 m.g.d. capacity must be ready for service a few miles west of Division Station, with pumping station and filtration plant here also built at first only to half capacity, provision being made for doubling later. Both of these stations will pump some water to low service, and some to first high service, and the New East Station will send some direct to second high. The existing East Side 2nd high service reservoir at Warrensville will have to be increased in capacity; and a West Side first high service reservoir built, from which the relatively small amounts of water needed for West Side second and third high service will be boosted to a reservoir for second high and to a standpipe for third high.

I wish to give credit to the ability, patience and care with which Mr. W. H. Knox has carried through, under my direction, the complicated investigations and computations on this part of our work, in planning our program of future expansion.

The cost of construction during the next twenty years excluding normal growth of the distribution system, will run about $25,000,000.